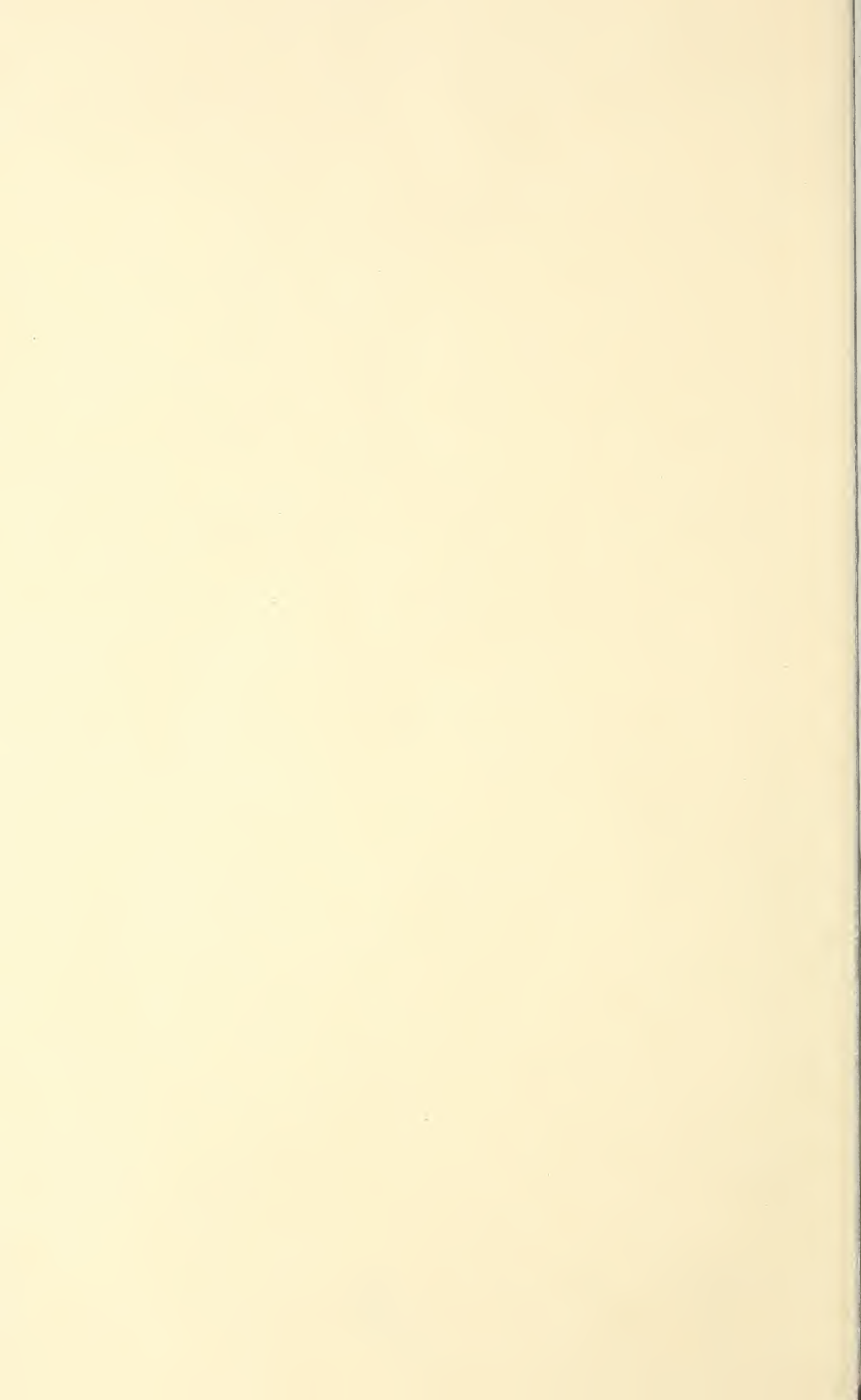
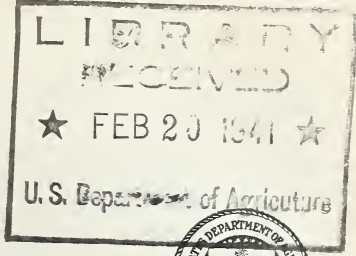


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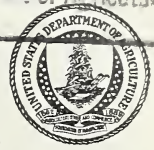
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Bacterial Wilt of Alfalfa and Its Control¹

By FRED R. JONES, *senior pathologist, Division of Forage Crops and Diseases, Bureau of Plant Industry*

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IMPORTANCE OF THE DISEASE

For a number of years bacterial wilt² has been recognized as the most important disease of alfalfa in the United States. When first discovered, it was already well established in most of the better alfalfa-growing regions extending across the middle of the United States almost from coast to coast. In most localities of this central belt it soon became rather uniform in its occurrence, and during the past few years has increased very slowly. Increased severity is indicated chiefly by reports of fields dying from wilt earlier than in previous years.

To the north and south of this central belt and in mountain valleys and isolated irrigation projects, the disease appears to be still spreading, though perhaps more slowly than across the center of the country. Because there is little accurate information regarding the recent advance of the disease and its present limits, there is little basis for predicting its ultimate distribution; however, there seems to be no reason why it should not spread to all alfalfa-growing localities where moisture conditions favor it.

In areas of low annual rainfall, about 25 inches or less, alfalfa remains relatively or completely free from the disease and apparently will remain so unless water is supplied by irrigation. In regions of

¹ Cooperative investigations of the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the Wisconsin Agricultural Experiment Station.
² Caused by the bacterium *Phytophthora infestans* (McC.) Bergey et al.

marginal rainfall the disease appears to vary directly with seasonal rainfall. Wilt is a disease of well-watered, highly productive alfalfa.

When the importance of wilt was recognized, plants resistant to the disease were found, chiefly in Turkistan alfalfa but also in some recent introductions that had not yet come into extensive use. These recent introductions were tested widely to determine whether, in the presence of wilt, they were superior to the varieties in common use. In addition, alfalfa-breeding projects were undertaken to furnish more highly resistant and suitable strains than appeared to be available at that time.

The time during which these tests have been carried on has been too short to develop, test, and put into production new wilt-resistant strains of alfalfa, but it has been long enough to gain ample evidence that such strains can be produced. If wilt does not shorten the productive life of a stand below the minimum required in a locality, because of the short rotation employed, little is gained from using alfalfa having some degree of resistance to wilt. The chief end sought by the use of wilt-resistant alfalfa, or by any other method of controlling wilt, is longer duration of the stand with maintained productivity. Continued productivity is emphasized because it has been observed that a diseased field may still have a good stand, but the yield may be greatly reduced by the disease.

DESCRIPTION OF THE DISEASE

Bacterial wilt of alfalfa is caused by bacteria that have the ability to grow between the living cells of the plant where these may be exposed, as in a wound, and to enter the water-carrying vessels. Here they increase and are distributed extensively through the plant by moving water until the vessels are obstructed. In addition they pass out again from such vessels among surrounding cells to gain nourishment and to enter new vessels as they are formed. In this advance they usually injure or kill some of the young cells forming the new growth. If the bacteria advance so rapidly that many young cells are killed, the plant usually wilts and dies quickly. Usually the bacteria grow so slowly that the infected plant is able to survive for a time with an altered habit of growth so conspicuously different from the usual habit that the disease is readily recognized thereby.

The first symptom of wilt likely to attract attention is a dwarfing and yellowing of the entire plant. Stems are short, the leaves are small and pale, many yellow at the edges, which curl upward, and the growth is slow (fig. 1). Such plants are most conspicuous after cutting, when the subsequent crop is about half grown (fig. 2). Later the dwarfed plants may be so completely overgrown that they do not attract attention unless they are numerous. However, even before this late stage of disease development, other less conspicuous symptoms may indicate that a plant is infected. For instance, during a hot midday a seemingly healthy but nevertheless slightly diseased plant may show a few characteristically wilted and yellowed leaves. Also on light soils not abundantly supplied with water, infected plants may wilt, though wilting does not often occur.

By the time the disease can be detected in the foliage, it has already done much damage to the root. The bacteria in the vessels of the

youngest wood discolor those vessels in a ring close beneath the bark. This discoloration is best seen when the root is cut across close below the crown (fig. 3), though it extends to the end of the taproot. The discolored wood is also seen when the bark is stripped from the wood. In the earliest development of the disease, the yellow color is found in strands or strips of the woody tissue extending down the root from the crown, but these strands soon merge into a continuous ring in the woody part of the root. In some old plants through which the bac-



FIGURE 1.—Bacterial wilt of alfalfa. A shoot from a healthy plant (left) compared with one from a severely diseased plant (right). The small yellowed, curled leaves on short stems are characteristic of the disease.

teria have advanced slowly, two or more distinct rings can be distinguished in the wood. In young, vigorous plants the discolored rings are wider than in old plants. In almost all parts of the United States, dwarfed, yellow or pale-green foliage, associated with discolored wood in the root, unmistakably indicates bacterial wilt.

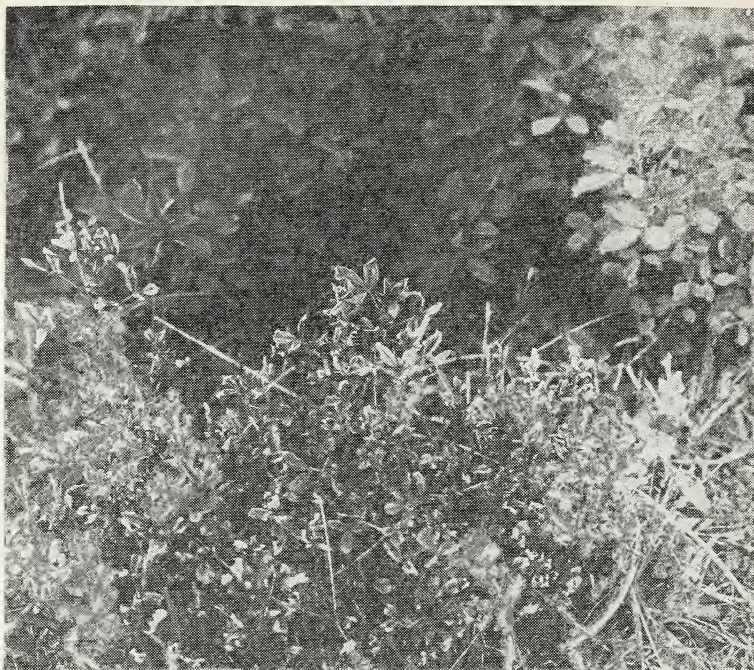


FIGURE 2.—Bacterial wilt of alfalfa. Characteristic growth of diseased plants in autumn is shown in the foreground. The curled leaves of the plant at the left in the background indicate that this plant also is diseased, though not so severely as the plants in the foreground.

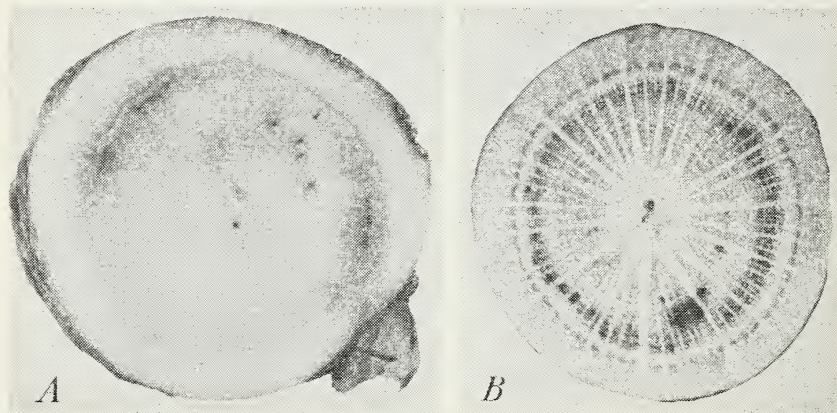


FIGURE 3.—Cross section of roots of alfalfa plants infected with wilt. *A*, A recent infection in a vigorous second-year plant. Discoloration from disease is found only between the 9- and 12-o'clock and the 3- and 4-o'clock positions of this section, which was taken about 2 inches below the crown. Disease symptoms had appeared above ground in only a few leaves on two or three shoots at one side of the plant. The plant was growing with undiminished vigor, overgrowing the disease temporarily (at the level of this section), as the discolored region does not extend entirely to the cambium. *B*, A section of a root diseased in its third year of growth. The discolored circle extends all the way to the cambium. Plants with roots in this condition have foliage like that shown in the foreground of figure 2.

With age, alfalfa fields become increasingly liable to injury from bacterial wilt. In an extensive field study of the disease in irrigated fields in Wyoming the percentage of wilt in fields was found to increase with age in general up to 5 years, when 45 percent of the plants were infected. However, wilt may develop suddenly in fields of any age. Nearly 90 percent of the plants were infected in one second-year field in Wyoming. The conditions that make possible such early and devastating attacks seem to be an abundant source of infection from old plants, winter damage, and abundant moisture in the spring.

OTHER DISEASES RESEMBLING BACTERIAL WILT

Three other alfalfa diseases of local distribution at present may be easily confused with bacterial wilt. They are witches' broom, dwarf disease, and a fusarium wilt. These are distinguished as follows.

Witches' broom of alfalfa, known at present locally in the Salt Lake Valley in Utah and in western Washington and northern Idaho, resembles bacterial wilt in showing foliage dwarfed in much the same manner but differs in the fact that the wood of the root is not discolored.

Dwarf disease found in the southern part of California, chiefly south of the Tehachapi Mountains, resembles wilt both in the dwarfing of foliage and in the discoloration in the root, but is distinguished by the normal green color of the dwarfed foliage in contrast with the pale-green or yellow color characteristic of bacterial wilt.

Fusarium wilt of alfalfa, reported from northeastern Mississippi and the southern part of California, is a wilt disease in which the root is more deeply discolored than in bacterial wilt, but in which wilting and death are not preceded by dwarfing or discoloration of the foliage. Only in these regions are other diseases likely to be mistaken for bacterial wilt at the present time.

CONTROL OF WILT BY CULTURAL PRACTICES

Experimental data on the effectiveness of such cultural practices as length of rotation and methods of irrigation in the control of wilt are meager. The bacteria that cause wilt seem to be resistant to drought and also seem to be carried easily and extensively in dust and especially in water. Thus the control of the disease by rotation evidently does not offer as much opportunity for success with this as with many wilt diseases. There are, however, a few precautions that tend to retard the appearance of disease in new seedings.

In replanting fields in which a diseased stand has been plowed under, it has often been noted that diseased plants escaping the plow become centers of infection in the new stand and lead to a more rapid destruction of that stand than occurs when all plants have been killed and allowed to decay. Therefore, diseased plants should be thoroughly turned under and allowed to decay before a new seeding is made, but rotation for a longer period than is required for this purpose has not yet been shown to be effective in retarding the disease. Wilt may develop more tardily in seedings on land that has not had a previous stand of diseased alfalfa.

In the management of alfalfa fields several practices apparently hasten the development of wilt. Late fall cutting or any cutting treatment that reduces the vigor of the stand may be followed by a rapid development of the disease. Infected plants die more quickly

and infection takes place more rapidly when a vigorous stand is thus checked in growth.

Cultivating fields and pasturing, especially when the ground is wet, are likely to result in wounds through which the bacteria may enter and may therefore lead to a rapid spread of the wilt.

Under irrigation the disease appears to be increased by excessive use of water, especially when fields are not allowed to dry out to some extent during part of the summer.

Thus, where wilt is established, cultural methods may be modified to delay its appearance and development to some extent, but their employment must be developed in relation to local experience and practices.

CONTROL OF WILT BY THE USE OF RESISTANT VARIETIES

The main experimental effort in the control of wilt has been directed toward, first, comparing strains known to contain resistant plants, and, second, breeding new strains that shall have a large proportion of resistant plants as well as other desirable characters. Although too short a time has elapsed for many results to become available, the results of methods already being used in the production of new alfalfas appear not only to insure the ultimate success of that effort but also to furnish information of use in interpreting field trials of varieties.

Resistant plants for breeding purposes are obtained by inoculating large populations of seedlings and selecting those that remain free from disease at the end of a suitable period in the field or greenhouse. Such selected plants have been found to differ greatly in ability to transmit this resistant character, and thus it is usually necessary to test the progeny of each plant as a second step in the selection of desirable breeding material.

In the course of this testing work it has been found that plants differ in the ease with which they are infected, and especially in the rate at which wilt develops in them. Resistance thus appears to occur in different degrees in plants, and even in a given plant it is not a simple fixed quality under all conditions, though in a few it seems to amount to immunity.

Because of this varying degree of resistance in plants, it is not possible at present to measure precisely the percentage of plants in a variety that will withstand wilt over a long period of time under all conditions. However, provisional estimates have been made for purposes of comparison. Peruvian alfalfa, Grimm, Hardigan, and the common varieties contain very few resistant plants, usually less than 1 percent, though local strains believed to be derived from Turkistan alfalfa or with some admixture from this source have more. Cossack alfalfa usually has less than 10 percent of resistant plants. In Ladak about a third of the plants usually appear highly resistant, and in Hardistan and Orestan and other more resistant strains from Turkistan importations about half of the plants may be so classed.

The results of these comparatively rapid controlled tests of alfalfa varieties have been helpful in predicting the outcome of long-time field trials. It is from field trials that the value of varieties in avoiding loss from this disease must be determined.

In the many field trials that have been undertaken during recent years Hardistan, Orestan, and similar strains of Turkistan alfalfa have exceeded all others in longevity, and comparatively little evidence of damage from wilt has been found in field plots of these varieties at any time.

In field tests and also in controlled tests, Ladak has shown a greater variation in longevity and of disease development in comparison with Grimm and common alfalfa than has Hardistan. In many tests Ladak has shown marked superiority in longevity; sometimes it has shown little advantage. At present it appears that the relative success or failure of Ladak may have been dependent upon regional conditions either preventing or favoring rapid and severe development of the disease.

Wherever disease has developed so slowly that but few susceptible plants are infected and killed in a single season, Ladak maintained a profitable stand far longer than varieties having practically no resistant plants. On the other hand, where conditions favoring disease development have appeared so suddenly that nearly all of the susceptible plants were infected and killed at the same time, the remaining resistant plants seem to have been too few to fill the vacant space and retain a profitable stand. The extreme conditions favoring disease, in which Ladak is of little practical value, appear to occur chiefly under irrigation and on land where wilt has been present in previous alfalfa stands.

For the present, the utility of Ladak in avoiding loss from wilt must be decided from regional experience based on field trials, the outcome of which is often determined not alone by resistance to wilt but by other characters that make a variety adapted to a region. Even Cossack alfalfa with but few resistant plants may be preferable to Grimm with almost none, since in addition it has other characters that give it persistence where wilt is not so severe as to ruin the stand promptly. Practically, Ladak and even Cossack are necessarily chosen at present because more seed of these varieties is available than of Hardistan, Orestan, or other resistant selections. However, in making this practical choice, Cossack can hardly be called a resistant variety, and the limitations in the resistance of Ladak should be fully recognized.

Hardistan and Orestan, developed in Nebraska and Oregon, respectively, from Turkistan alfalfa, are among the highly resistant strains from this source as determined both by controlled tests and field trials, and they show the high standard of resistance attainable in a resistant variety. Varieties produced by the breeding work now in progress will probably equal or exceed this standard.

However, Hardistan has shown low seed-yielding ability thus far, and thus is likely to be outstripped in production by selections that set seed freely. Hardistan and Orestan, like other Turkistan derivatives, may prove conspicuously susceptible to leaf diseases in the more humid regions. On the other hand, Hardistan and Orestan have a high degree of winter hardiness much needed in the northern part of the wilt-infested region.

At present the seed supply of Hardistan and Orestan alfalfa is very limited. Information regarding possible seed sources of the former may be obtained by writing the Nebraska Agricultural Experiment

Station, Lincoln, Nebr., and of the latter by writing the Oregon Agricultural Experiment Station, Corvallis, Oreg.

It is probable that in most localities, even by the use of the most highly resistant varieties developed by selection and breeding, alfalfa will not live as long as formerly. Fungus and bacterial diseases of less importance than bacterial wilt have accumulated with the continued growing of the crop, and these are undoubtedly reducing stands, especially in regions of higher rainfall. Some of these diseases are recognized at present, and plant breeders are taking every opportunity to select for resistance to them. Thus the breeding program for alfalfa, stimulated by the advent of wilt, has much more extensive aims than resistance to that disease alone.

FUTURE PROSPECTS FOR CONTROL

Bacterial wilt is a permanently established enemy of the alfalfa crop and may continue to spread somewhat beyond present boundaries. Its severity is likely to increase rather than diminish with the return of alfalfa to fields previously occupied by diseased stands. The disease may be retarded in development somewhat by management that keeps the stand in vigorous condition and avoids injury to the crowns. Effective control lies chiefly in the use of varieties in which resistance is combined with other characters that make the variety adapted to the region in which it is used. Partially resistant varieties now available will extend the life of alfalfa fields somewhat, except in localities where the disease develops with the greatest rapidity and severity. Highly resistant lines of alfalfa have been selected, and it is from these lines that new varieties are being developed that may not only make the disease practically unimportant but, it is hoped, will exceed present varieties in yield.

